

Supplementary Material (SM)

Development of A Composite Sustainability Index Within An Integrated Coastal Zone Management Framework: A Case Study of Ho Chi Minh City, Vietnam

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Table S1 The preliminary criteria

No.	Criteria	Unit	Description	Reference
Socio-economic index				
1	Population density	People km ⁻²	Population concentration per unit area, where higher values increase exposure and vulnerability	Zuo et al. (2025)
2	Poverty rate	%	Proportion of households below the poverty standard, where higher values indicate lower economic development	Tan et al. (2023)
3	Income	USD month ⁻¹	Average monthly income per capita, where higher values reflect stronger economic capacity and livelihood security	Shah et al. (2025)
4	Unemployment rate	%	Proportion of the labor force without employment, where higher values indicate lower labor market efficiency	Mafi-Gholami et al. (2026)
5	Permanent housing rate	%	Share of durable housing, where higher values indicate better living conditions and resilience	Mafi-Gholami et al. (2026)
6	Education	%	High school graduation rate, where higher values reflect better education access and human capital quality	Schernewski et al. (2014)
7	Healthcare	People	Number of healthcare personnel, where higher values indicate stronger healthcare capacity and resilience	Schernewski et al. (2014)
8	Urban traffic rate	%	The efficiency of transport infrastructure utilization, where higher values indicate greater sustainability	Ding et al. (2025)
9	FDI investment ratio in the marine economy	% year ⁻¹	The proportion of foreign direct investment (FDI) allocated to the marine economy, where higher values indicate stronger economic sustainability	Wei et al. (2014)
Eco-environmental index				
1	Inundation area	%	Proportion of area under regular inundation, where higher values indicate greater exposure	Tran et al. (2025)
2	Coastal material	–	Surface material of the coastal zone, with natural materials indicating higher resilience	Cuong et al. (2023)
3	Shoreline change rate	m year ⁻¹	Rate of shoreline movement over time, where higher values indicate greater instability	Ahmadi et al. (2026)
4	Coastal forest coverage	%	Proportion of coastal forest area, where higher values indicate stronger ecological protection	Zhang et al. (2024)
5	NH ₄ ⁺ concentration	mg L ⁻¹	Ammonium concentration in water, where higher values indicate higher pollution levels	Liu et al. (2025)
6	DO concentration	mg L ⁻¹	Dissolved oxygen in water, where higher values indicate better water quality	Mariscal-de-Souza et al. (2026)
7	PM10 concentration	µg m ⁻³	Particulate matter (≤ 10 µm) concentration in air, where higher values indicate higher pollution	Aryee et al. (2018)
8	SO ₂ concentration	µg m ⁻³	Sulfur dioxide concentration in air, where higher values indicate higher pollution	Fu et al. (2026)
9	Nature reserve area	km ²	The extent of protected areas for biodiversity, forestry, and fisheries conservation, where higher coverage indicates greater sustainability	Aryee et al. (2018)
1	Environmental communication	–	Implementation of formal environmental communication programs, where higher values indicate stronger public awareness	Kurniati et al. (2024)
2	Management personnel	People	Number of environmental management personnel, where higher values indicate stronger capacity	Kurniati et al. (2024)
3	Environmental violation	Cases	Number of recorded environmental violations, where higher values indicate weaker compliance	Tran et al. (2024)
4	Monitoring system	Stations	Number of environmental monitoring stations, where higher values indicate stronger monitoring capacity	Wan et al. (2014)
5	Environmental expenditure	%	Share of budget for environmental protection, where higher values indicate stronger support	Walling et al. (2024)
6	Level of ICZM implementation	–	The level of local government participation in coastal zone management. Higher levels indicate greater sustainability.	Walling et al. (2024)

Table S2 GBWM expert consultation matrix

Index	Criteria	Best-to-criterion preference (a_{Bi})	Criterion-to-worst preference (a_{iW})
Socio-economic index	SE_1		
	SE_2		
	$SE_3 (B)$	1	
	SE_4		
	$SE_5 (W)$		1
	SE_6		
	SE_7		
Eco-environmental index	EE_1		
	EE_2		
	EE_3		
	$EE_4 (B)$	1	
	EE_5		
	EE_6		
	EE_7		
	$EE_8 (W)$		1
Institutional-management index	$IM_1 (W)$		1
	IM_2		
	IM_3		
	$IM_4 (B)$	1	
	IM_5		
Component Sustainability index	$SEI (W)$		1
	$EEI (B)$	1	
	IMI		

Note: B and W denote the best and worst criteria, respectively. Experts assigned preference scores using a 1–9 scale; self-comparisons were assigned a value of 1.

Table S3a Expert preference judgments for socio-economic criteria

Experts	Criteria		SE_1	SE_2	SE_3	SE_4	SE_5	SE_6	SE_7
	Best	Worst							
Expert 1	SE_3		2	3	–	2	2	5	4
		SE_5	4	5	2	3	–	3	3
Expert 2	SE_3		2	3	–	3	3	3	3
		SE_5	3	2	3	3	–	3	3
Expert 3	SE_3		3	4	–	5	5	2	4
		SE_5	3	5	5	7	–	5	6
Expert 4	SE_3		3	3	–	3	5	3	2
		SE_5	2	4	5	4	–	3	3
Expert 5	SE_3		3	6	–	6	4	4	4
		SE_5	4	3	4	5	–	3	2
Expert 6	SE_3		2	2	–	3	3	2	2
		SE_5	5	5	3	5	–	7	7
Expert 7	SE_3		3	3	–	3	2	2	2
		SE_5	5	3	2	3	–	4	4
Expert 8	SE_3		6	5	–	6	4	4	4
		SE_5	8	6	4	6	–	7	7
Expert 9	SE_3		3	4	–	5	5	5	4
		SE_5	5	5	5	5	–	5	4
Expert 10	SE_3		2	2	–	4	5	3	3
		SE_5	7	9	5	5	–	5	7
Expert 11	SE_3		4	3	–	3	7	2	3
		SE_5	3	3	7	5	–	5	3
Expert 12	SE_3		3	2	–	3	4	3	2
		SE_5	6	6	4	5	–	3	3

Table S3b Expert preference judgments for eco-environmental criteria

Experts	Criteria		EE_1	EE_2	EE_3	EE_4	EE_5	EE_6	EE_7	EE_8
	Best	Worst								
Expert 1	EE_4		3	5	3	–	3	3	2	2
		EE_8	5	5	4	2	4	3	3	–
Expert 2	EE_4		4	5	3	–	4	3	3	3
		EE_8	3	5	7	3	5	4	4	–
Expert 3	EE_4		5	7	5	–	5	3	5	5
		EE_8	5	3	3	5	3	4	3	–
Expert 4	EE_4		3	6	5	–	5	3	3	3
		EE_8	3	3	3	3	2	2	2	–
Expert 5	EE_4		7	7	3	–	7	7	7	8
		EE_8	7	7	8	8	7	7	7	–
Expert 6	EE_4		2	5	3	–	3	2	2	2
		EE_8	4	4	5	2	3	3	7	–
Expert 7	EE_4		4	5	4	–	4	3	3	3
		EE_8	2	2	2	3	3	3	2	–
Expert 8	EE_4		7	7	7	–	7	7	7	7
		EE_8	7	8	7	7	6	6	6	–
Expert 9	EE_4		6	7	5	–	5	6	5	5
		EE_8	7	8	8	5	6	8	9	–
Expert 10	EE_4		5	5	5	–	5	7	7	5
		EE_8	9	8	7	5	8	8	7	–
Expert 11	EE_4		5	7	3	–	3	5	5	5
		EE_8	5	5	3	5	3	4	4	–
Expert 12	EE_4		3	5	3	–	2	2	2	3
		EE_8	3	5	4	3	4	3	5	–

Table S3c Expert preference judgments for institutional-management criteria

Experts	Criteria		<i>IM</i> ₁	<i>IM</i> ₂	<i>IM</i> ₃	<i>IM</i> ₄	<i>IM</i> ₅
	Best	Worst					
Expert 1	<i>IM</i> ₄		7	5	5	–	5
		<i>IM</i> ₁	–	3	3	7	3
Expert 2	<i>IM</i> ₄		5	4	3	–	3
		<i>IM</i> ₁	–	3	5	5	5
Expert 3	<i>IM</i> ₄		5	3	3	–	2
		<i>IM</i> ₁	–	5	4	5	4
Expert 4	<i>IM</i> ₄		6	5	4	–	4
		<i>IM</i> ₁	–	3	2	6	2
Expert 5	<i>IM</i> ₄		9	7	7	–	7
		<i>IM</i> ₁	–	6	6	9	6
Expert 6	<i>IM</i> ₄		5	3	3	–	2
		<i>IM</i> ₁	–	7	5	5	5
Expert 7	<i>IM</i> ₄		7	5	3	–	3
		<i>IM</i> ₁	–	5	6	7	6
Expert 8	<i>IM</i> ₄		3	2	2	–	2
		<i>IM</i> ₁	–	3	3	3	3
Expert 9	<i>IM</i> ₄		9	7	8	–	8
		<i>IM</i> ₁	–	5	3	9	2
Expert 10	<i>IM</i> ₄		6	5	3	–	5
		<i>IM</i> ₁	–	7	8	6	4
Expert 11	<i>IM</i> ₄		3	2	2	–	2
		<i>IM</i> ₁	–	3	5	3	6
Expert 12	<i>IM</i> ₄		5	4	4	–	4
		<i>IM</i> ₁	–	5	8	5	7

Table S3d Expert preference judgments for the component indices of the composite sustainability index

Experts	Criteria		SEI	EEI	IMI
	Best	Worst			
Expert 1	EEI	SEI	2	–	2
Expert 2	EEI	SEI	2	–	2
Expert 3	EEI	SEI	2	–	2
Expert 4	EEI	SEI	2	–	2
Expert 5	EEI	SEI	2	–	2
Expert 6	EEI	SEI	2	–	2
Expert 7	EEI	SEI	3	–	2
Expert 8	EEI	SEI	3	–	1
Expert 9	EEI	SEI	2	–	1
Expert 10	EEI	SEI	2	–	2
Expert 11	EEI	SEI	1	–	2
Expert 12	EEI	SEI	1	–	3

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